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FILING DATE: *April 28, 2004*

By Authority of the
COMMISSIONER OF PATENTS AND TRADEMARKS

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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

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INVENTOR(S)

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Additional inventors are being named on the ONE *separately numbered sheets attached hereto*

TITLE OF THE INVENTION (500 characters max)

METHOD AND APPARATUS OF MAPPING MIMO SIGNAL ONTO OFDM ACCESS SUB-CARRIERS

Direct all correspondence to: CORRESPONDENCE ADDRESS

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OR

☐ Firm or Individual Name					
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ENCLOSED APPLICATION PARTS *(check all that apply)*

☑ Specification *Number of Pages* 15

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☐ Application Data Sheet. See 37 CFR 1.76

☐ CD(s), Number ______

☐ Other (specify) ______

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT

☐ Applicant claims small entity status. See 37 CFR 1.27.

☐ A check or money order is enclosed to cover the filing fees.

☑ The Director is herby authorized to charge filing fees or credit any overpayment to Deposit Account Number: 50-0210

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The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

☑ No.

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[Page 1 of 2]

Respectfully submitted,

SIGNATURE [signature]

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Date APRIL 28, 2004

REGISTRATION NO. 31,618
(if appropriate)
Docket Number: 17008ROUS01P

USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

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Docket Number	17008ROUS01P

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Provisional Patent Application

Title:

Method and Apparatus of Mapping MIMO Signal onto OFDM Access Sub-Carriers

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Submitted:

April 28, 2004

METHOD & APPARATUS FOR MAPPING MIMO SIGNALS ONTO OFDMA SUBCARRIERS

1. SPACE TIME FREQUENCY MAPPING FOR 4-TRANSMIT ANTENNAS

For OFDM (orthogonal frequency division multiplexing) signalling, the space-time coding can be mapped onto either the time direction or the frequency direction. In this disclosure, we present a novel mapping that utilizes both time and frequency mapping, while providing for the entire antenna transmit on each sub-carrier based on the code format. Advantages for this mapping include minimizing the time-frequency span to ensure the space time code span within both coherent-time and coherent-frequency range. This approach can be generalized into more antennas for OFDMA (OFDM Access) Mapping. The following are the new space time code constructions:

1. Code-1: Code rate ¾ space time frequency code
2. Code-2A: Code rate 1 space time frequency code, decodeable with Alamouti decoder.
3. Code-2B: Code rate 1 space time frequency code, Antenna hopped version of Code-2A
4. Code-2C: Code rate 1 space time frequency code, Antenna hopped version of Code-2A
5. Code-3A: Code rate 2 space time frequency code
6. Code-3B: Code rate 2 space time frequency code, Antenna permuted version of Code-3A
7. Code-4: Code rate 4 space time frequency code

Table 1 Code-1

	Time t Sub-carrier k	Time $t+T$ Sub-carrier k	Time t Sub-carrier $k+1$	Time $t+T$ Sub-carrier $k+1$
Antenna 1	s_1	$-s_2^*$	$-s_3^*$	×
Antenna 2	s_2	s_1^*	×	s_3^*
Antenna 3	s_3	×	s_1^*	$-s_2^*$
Antenna 4	×	$-s_3$	s_2	s_1

Table 2 Code-2A

	Time t Sub-carrier k	Time $t+T$ Sub-carrier k	Time t Sub-carrier $k+1$	Time $t+T$ Sub-carrier $k+1$
Antenna 1	s_1	$-s_2^*$	0	0
Antenna 2	s_2	s_1^*	0	0
Antenna 3	0	0	s_3	$-s_4^*$
Antenna 4	0	0	s_4	s_3^*

Table 3 Code-2B

	Time t Sub-carrier k	Time $t+T$ Sub-carrier k	Time t Sub-carrier $k+1$	Time $t+T$ Sub-carrier $k+1$
Antenna 1	s_1	$-s_2^*$	0	0
Antenna 2	0	0	s_3	$-s_4^*$
Antenna 3	0	0	s_4	s_3^*
Antenna 4	s_2	s_1^*	0	0

Table 4 Code 2C

	Time t Sub-carrier k	Time $t+T$ Sub-carrier k	Time t Sub-carrier $k+1$	Time $t+T$ Sub-carrier $k+1$
Antenna 1	s_1	$-s_2^*$	0	0
Antenna 2	0	0	s_3	$-s_4^*$
Antenna 3	s_2	s_1^*	0	0
Antenna 4	0	0	s_4	s_3^*

Table 5 Code-3

	Time t Sub-carrier k	Time $t+T$ Sub-carrier k	Time t Sub-carrier $k+1$	Time $t+T$ Sub-carrier $k+1$
Antenna 1	s_1	$-s_2^*$	s_5	$-s_7^*$
Antenna 2	s_2	s_1^*	s_6	$-s_8^*$
Antenna 3	s_3	$-s_4^*$	s_7	s_5^*
Antenna 4	s_4	s_3^*	s_8	s_6^*

Table 6 Code-4

	Time t Sub-carrier k	Time $t+T$ Sub-carrier k	Time t Sub-carrier $k+1$	Time $t+T$ Sub-carrier $k+1$
Antenna 1	s_1	$-s_2^*$	s_5	$-s_7^*$
Antenna 2	s_2	s_1^*	s_7	$-s_8^*$
Antenna 3	s_3	$-s_4^*$	s_6	s_5^*
Antenna 4	s_4	s_3^*	s_8	s_6^*

Table 7 Code-5

	Time t Sub-carrier k	Time $t+T$ Sub-carrier k	Time t Sub-carrier $k+1$	Time $t+T$ Sub-carrier $k+1$
Antenna 1	s_1	s_5	s_9	s_{13}
Antenna 2	s_2	s_6	s_{10}	s_{14}
Antenna 3	s_3	s_7	s_{11}	s_{15}
Antenna 4	s_4	s_8	s_{12}	s_{16}

1.1 Adaptive STC and SFC approach

Since the space time code (STC) mapping in the time direction will lose the robustness of mobility and space frequency code (SFC) mapping in the frequency direction will loss the immunity of dispersive channel, we propose adaptive STC/SFC coding. In our design, the selection of the SFC and STC will be determined by the receiver (or transmitter in the TDD case).

2. PARTIAL ULTILIZED SUBCHANNEL FOR OFDMA

This a fractional frequency re-use version of the OFDMA signaling, in this case, sub-carriers are not fully loaded.

2.1 Partial Utilized Sub-Channel ("PUSC") Structure

The structure of the PUSC channel is listed in Table 8.

Table 8 the PUSC channel structure

Parameter	Value	Comment
Number of DC Subcarriers	1	Index 1024
Number of Guard Subcarriers, Left	183	
Number of Guard Subcarriers, Right	184	
Number of Used Subcarriers (*Nused*)	1681	Number of all subcarriers used within a symbol including all possible allocated pilots and the DC sub-carrier
Number of carriers per cluster	14	
Number of clusters	120	
Renumbering sequence	1	used to renumber clusters before allocation to subchannels: 6, 108, 37, 81, 31, 100, 42, 116, 32, 107, 30, 93, 54, 78, 10, 75, 50, 111, 58, 106, 23, 105, 16, 117, 39, 95, 7, 115, 25, 119, 53, 71, 22, 98, 28, 79, 17, 63, 27, 72, 29, 86, 5, 101, 49, 104, 9, 68, 1, 73, 36, 74, 43, 62, 20, 84, 52, 64, 34, 60, 66, 48, 97, 21, 91, 40, 102, 56, 92, 47, 90, 33, 114, 18, 70, 15, 110, 51, 118, 46, 83, 45, 76, 57, 99, 35, 67, 55, 85, 59, 113, 11, 82, 38, 88, 19, 77, 3, 87, 12, 89, 26, 65, 41, 109, 44, 69, 8, 61, 13, 96, 14, 103, 2, 80, 24, 112, 4, 94, 0
Number of clusters data subcarriers in each symbol per subchannel	24	
Number of clusters per subchannel	2	
Number of subchannels	60	
PermutationBase12 (for 12 subchannels)		6,9,4,8,10,11,5,2,7,3,1,0
PermutationBase8 (for 8 subchannels)	4	7,4,0,2,1,5,3,6

2.2 PUSC subchannel mapping

The network resource management will use the following OFDM subcarrier allocation method to mapped the traffic data onto the OFDM data resources.

The carrier allocation to subchannles is performed by a two stage process using the following procedure:

1. Dividing the subcarriers into a multitude of physical clusters (120 in this example) each containing a plurality of adjunct subcarriers (14 in this example), starting from carrier 0
2. Renumbering the physical clusters into logical clusters using the following formula:
   LogicalCluster = RenumberingSequence((PhysicalCluster+13*Cell_Id) mod 120)
3. Renumbering the clusters and dividing them Dividing the clusters into major groups:
   a. The 120 clusters are renumbered using the renumbering sequence which allocates a physical cluster n to a logical cluster $\pi(n)$ where π indicates the renumbering sequence (e.g. physical cluster 1 shall be allocated to logical cluster X).
   b. The logical cluster space shall be then divided into 6 major groups,
      i. group 0 includes clusters 0-230-11,
      ii. group 1 includes clusters 24-3912-19,
      iii. group 2 includes clusters 40-6320-31,
      iv. group 3 includes clusters 64-7932-39,
      v. group 4 includes clusters 80-10340-51,
      vi. group 5 includes clusters 104-11952-59.

      These groups are could be allocated to segments, where if a segment exists is being used then at least one group shall be allocated to it, by default
      1. group 0 is allocated to sector 0,
      2. group 1 2 is allocated to sector 1,
      3. group 2 4 is allocated to sector 2.

4. Allocating carriers to subchannel in each major group is performed by first allocating the pilot carriers within each cluster, and then taking all remaining data carriers within the symbol and All carriers from the group shall be logically joined in an ascending manner, partitioned into 12/8 groups (12 for even numbered groups, 8 for odd numbered groups), then using the same procedure with the parameters from Table 8 using the PermutationBase appropriate for each major group:
   a. PermutationBase12 for even numbered major groups and
   b. PermutationBase8 for odd numbered major groups

   to partition the subcarriers they will be partitioned into subchannels containing 24 data subcarriers in each symbol

2.3 Single Input Single Output ("SISO") PUSC Structure

The SISO subchannel structure is shown in Figure 1 as an prior art.

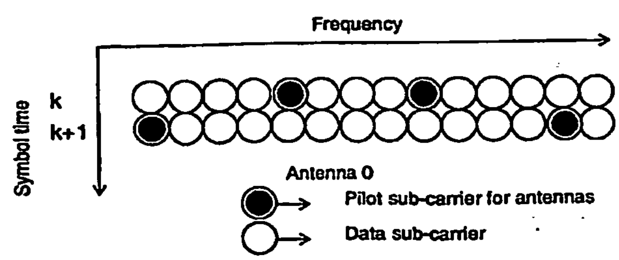

Figure 1 SISO Cluster Structure

2.4 2-transmit MIMO PUSC structure

In order to keep the same MAC layer assignment of the sub-carrier for data without changing the carrier numbering switching of the data carriers and the pilot's carriers shall be performed after constellation mapping, therefore maintaining the entire encoding scheme and the subchannel allocation scheme. In this scheme transmission on regular subchannels and STC subchannels is possible and is determined by the MAC (the allocation is performed by allocating major groups of subchannels for regular or STC transmission). We propose a new technique called the sub-carrier *swapping*; in this case, the pilot and data carriers are swapped. The detailed operation is shown in Figure 2 and Figure 3

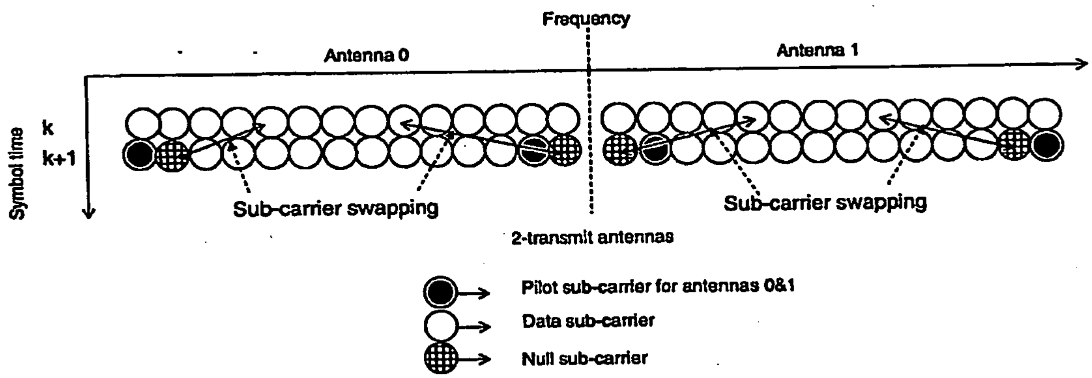

Figure 2 Sub-carrier swapping technique for SFC (Pattern-P2A)

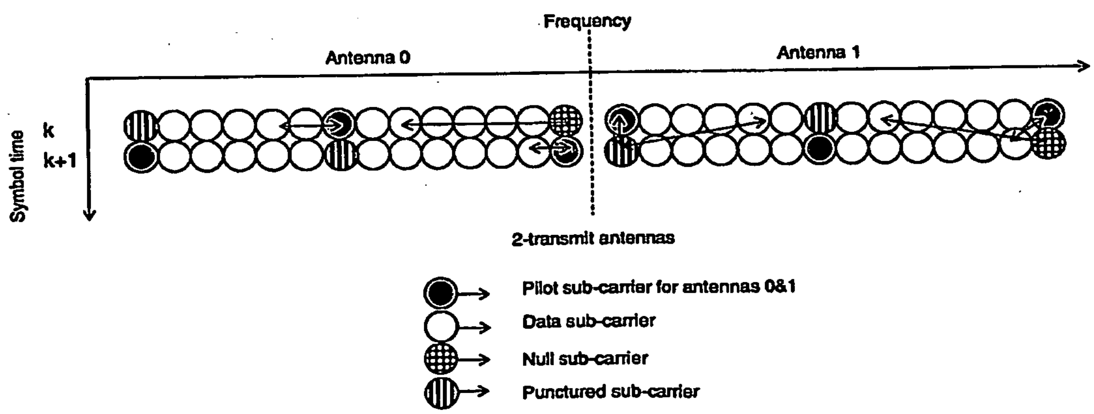

Figure 3 Sub-carrier swapping/puncture technique for STC (Pattern-P2B)

Another construction is to use pair-wise cluster based on the same principle of sub-carrier swapping. And the data sub-carrier can be arrangement that both space time coding and space frequency coding can be accommodated.

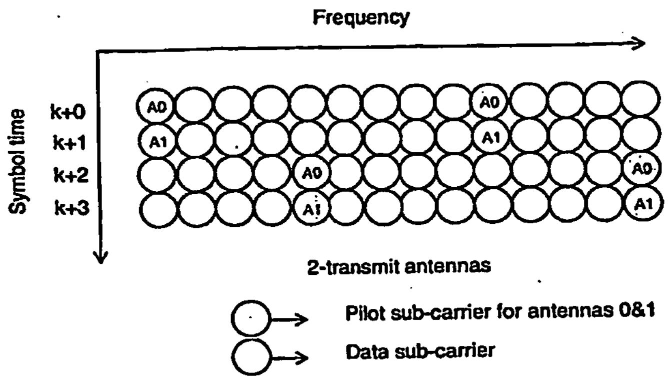

Figure 4 Sub-carrier swapping technique for STC and SFC (Pattern-P2C)

2.5 4-transmit MIMO PUSC structure

In order to keep the same MAC layer assignment of the sub-carrier for data without changing the carrier numbering switching of the data carriers and the pilot's carriers shall be performed after constellation mapping, therefore maintaining the entire encoding scheme and the subchannel allocation scheme. In this scheme transmission on regular subchannels and STC subchannels is possible and is determined by the MAC (the allocation is performed by allocating major groups of subchannels for regular or STC transmission). We propose a new technique called the sub-carrier *puncturing*; in this case, the pilot and data carriers are swapped. The detailed operation is shown in Figure 5 and Figure 6

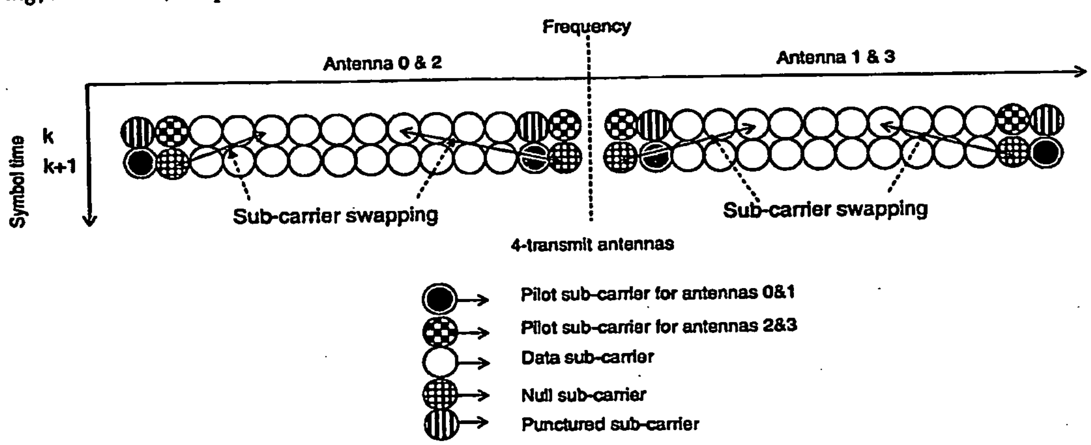

Figure 5 Sub-carrier swapping/puncture technique for both STFC (Pattern-P4A)

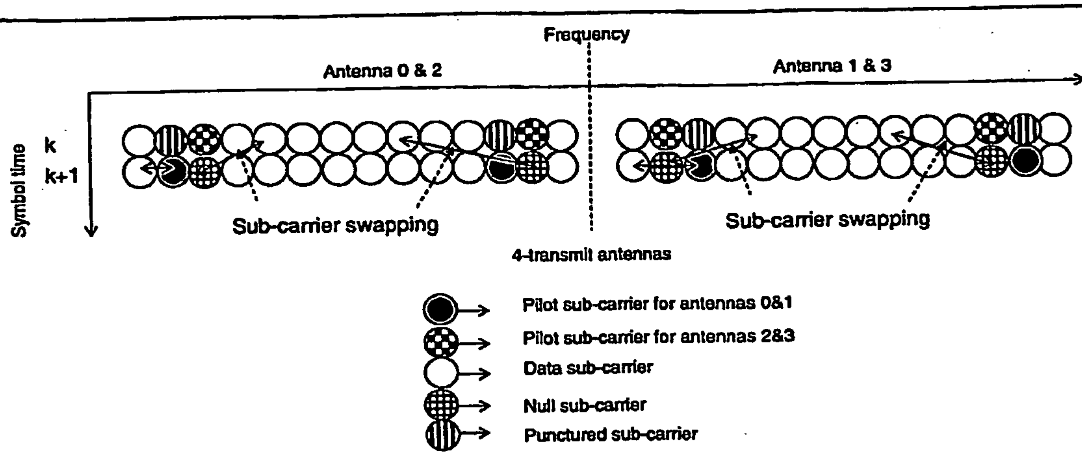

Figure 6 Sub-carrier swapping/puncture technique for STC (Pattern-P4B)

Another construction is to use pair-wise cluster based on the same principle of sub-carrier puncturing, this arrangement also can accommodate the STFC proposed in the 1st section.

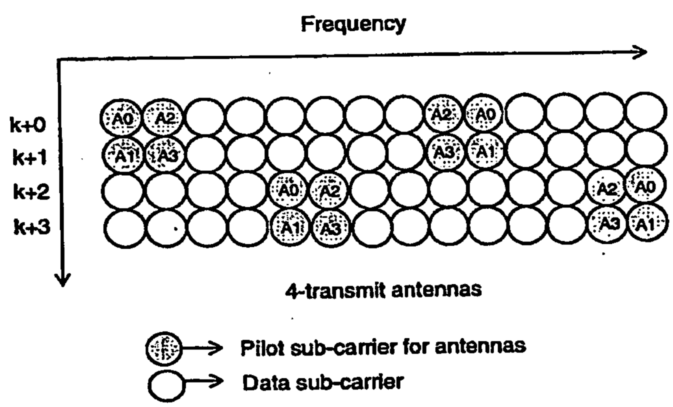

Figure 7 Sub-carrier swapping/puncture technique for both STFC (Pattern-P4C)

2.6 Fully Utilized Sub-Channel ("FUSC") Structure

2.7 FUSC subchannel structure

The structure of the PUSC channel is listed in Table 8.

Figure 8 the FUSC channel structure

Parameter	Value	Comment
Number of DC Subcarriers	1	Index 1024
Number of Guard Subcarriers, Left	172	
Number of Guard Subcarriers, Right	172	

Number of Used Subcarriers (*Nused*)	1703	Number of all subcarriers used within a symbol including all possible allocated pilots and the DC sub-carrier
Pilots		
VariableSet #0	24	0,72,144,216,288,360,432,504,576,648,720,792,864,936,1008,1080,1152,1224,1296,1368, 1440,1512,1584,1656
ConstantSet #0	4	39,645,1017,1407
VariableSet #1	24	36,108,180,252,324,396,468,540,612,684,756,828,900,972,1044,1116,1188,1260,1332,1404, 1476,1548,1620,1692
ConstantSet #1	4	261,,651,1143,1419 .
VariableSet #2	23	48,120,192,264,336,408,480,552,624,696,768,840,912,984,1056,1128,1200,1272,1344,1416, 1488,1560,1632
ConstantSet #2	4	330,726,1155,1461
VariableSet #3	24	12,84,156,228,300,372,444,516,588,660,732,804,876,948,1020,1092,1164,1236,1308,1380, 1452,1524,1596,1668
ConstantSet #3	4	342,849,1158,1530
VariableSet #4	24	24,96,168,240,312,384,456,528,600,672,744,816,888,960,1032,1104,1176,1248,1320,1392,1464, 1536,1608,1680
ConstantSet #4	4	351,855,1185,1545
VariableSet #5	23	60,132,204,276,348,420,492,564,636,708,780,852,924,996,1068,1140,1212,1284,1356,1428,1500, 1572,1644
ConstantSet #5	4	522,918,1206,1701
Number of data subcarriers	1536	
Number of data subcarriers per subchannel	48	
Number of Subchannels	32	
PermutationBase		3, 18, 2, 8, 16, 10, 11, 15, 26, 22, 6, 9, 27, 20, 25, 1, 29, 7, 21, 5, 28, 31, 23, 17, 4, 24, 0, 13, 12, 19, 14, 30

The Variable set of pilots embedded within the symbol of each segment shall obey the following rule:

PilotsLocation = VariableSet#x + 6* (FUSC_SymbolNumber mod 2)

Where FUSC_SymbolNumber counts the FUSC symbols used in the transmission starting from 0.

2.8 FUSC sub-channel mapping

There are 6/2 variable pilot-sets and 6/2 constant pilot-sets. In FUSC, each segment uses both sets of all variable/constant pilot-sets. In STC mode, each antenna uses half of the pilot set resources compared to that of non-STC mode. Table 271 summarizes the parameters of the symbol.
After mapping all segments pilots, the remainder of the used subcarriers are the data subchannels. Note that only the relevant pilots of the current segment are modulated, while all other pilots are zeroed. To allocate the data subchannels, the remaining subcarriers are partitioned into groups of contiguous subcarriers. Each subchannel consists of one subcarrier from each of these groups. The number of groups is therefore equal to the number of subcarriers per subchannel, and it is denoted. The number of the subcarriers in a group is equal to the number of subchannels, and it is denoted. The number of data subcarriers is thus equal to. The exact partitioning into subchannels is the permutation formula as follows:

$$Subcarrier(k,s) = N_{subchannels} * n_k + \{p_s[n_k \bmod N_{subchannels}] + ID_{cell}\} \bmod N_{subchannels}$$

Subcarrier(k, s) → is the subcarrier index of subcarrier *n* in subchannel *s*

s → is the index number of a subchannel, from the set [0.. $N_{subchannels}$ -1],

n_k =(k+13s)mod $N_{subchannels}$, where k is the subcarrier-in-subchannel index from the set

$N_{subchannels}$ → is the number of subchannels

p_s [j] → is the series obtained by rotating {*PermutationBase0*} cyclically to the left *s* times

ID_{cell} → is an integer ranging from 0 to 31, which identifies the particular BS segment
X_{mod} → is the remainder of the quotient X/k (which is at most $k-1$)

On initialization, a subscriber station SS (i.e., mobile terminal) searches for the downlink preamble. After finding the Preamble, the user shall know the ID_{cell} used for the data Subchannels.

2.9 Multiple density pilot set for adaptive pilot assignment

A large set of VariablepilotSet and FixedpilotSet are designed for different density usage of pilots. This allows best trade-off of the overhead and channel estimation quality. Such a pilot density allocation can be dynamic or static.

2.10 2-transmit MIMO FUSC structure

In FUSC all subchannles shall be used for STC transmission, the pilots within the symbols shall be divided between the antennas,

antenna 0 uses VariableSet#0 and ConstantSet#0 for even symbols
antenna 1 uses VariableSet#1 and ConstantSet#1 for even symbols
antenna 0 uses VariableSet#1 and ConstantSet#0 for odd symbols
antenna 1 uses VariableSet#0 and ConstantSet#1 for odd symbols

Symbol counting starts at the starting point of the relevant STC zone. The transmission of the data shall be performed in pairs of symbols. The figure illustrates how an STC transmission shall be performed, it shall be noted that when regular transmission is performed data subchannels are transmitted from antenna 0 only.

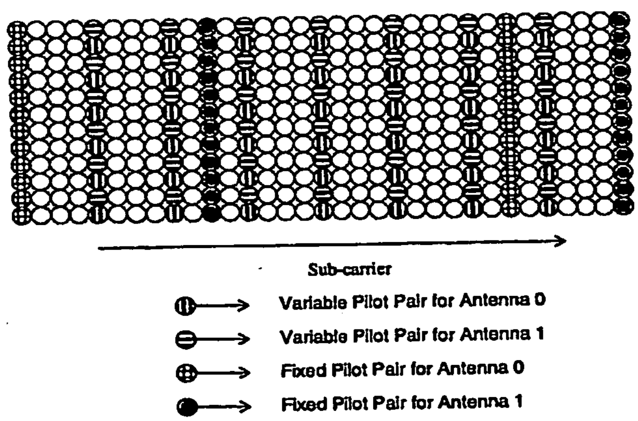

Figure 9 Variable and fixed pilot for 2 transmit antenna case (Pattern-F2A)

2.11 4-transmit MIMO FUSC structure

For the FUSC configuration the pilots embedded within the symbol shall be further divided, the pilots shall be transmitted with a structure including 4 time symbol (repeating itself every 4 symbols) as follows:

Symbol 0: antenna 0 uses VariableSet#0 and ConstantSet#0, antenna 1 uses VariableSet#1 and ConstantSet#1
Symbol 1: antenna 2 uses VariableSet#0 and ConstantSet#0, antenna 3 uses VariableSet#1 and ConstantSet#1
Symbol 2: antenna 0 uses VariableSet#1 and ConstantSet#0, antenna 1 uses VariableSet#0 and ConstantSet#1
Symbol 3: antenna 2 uses VariableSet#1 and ConstantSet#0, antenna 3 uses VariableSet#0 and ConstantSet#1

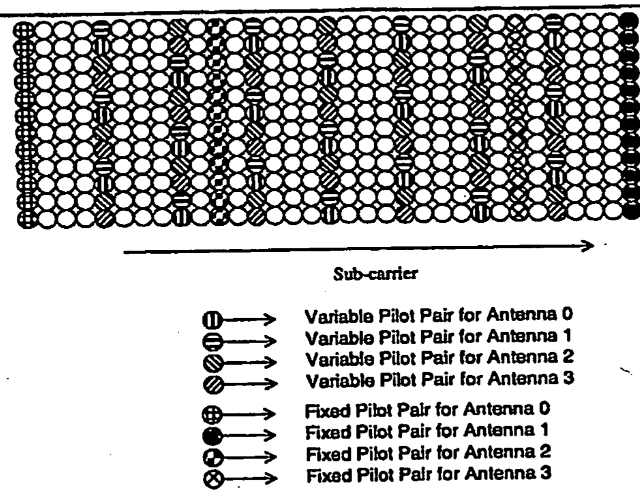

Figure 10 Variable and fixed pilot for 4 transmit antenna case (Pattern-F4A)

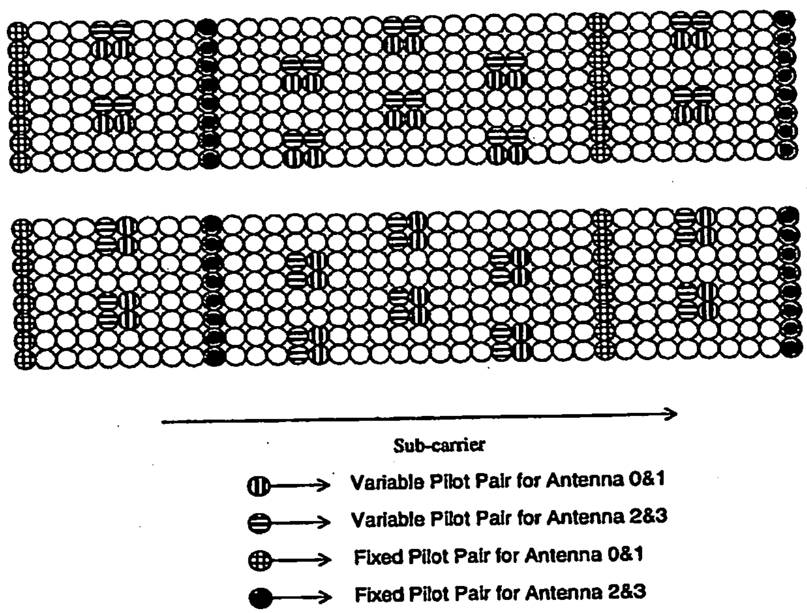

Figure 11 Variable and fixed pilot for 4 transmit antenna case (Pattern-F4B)

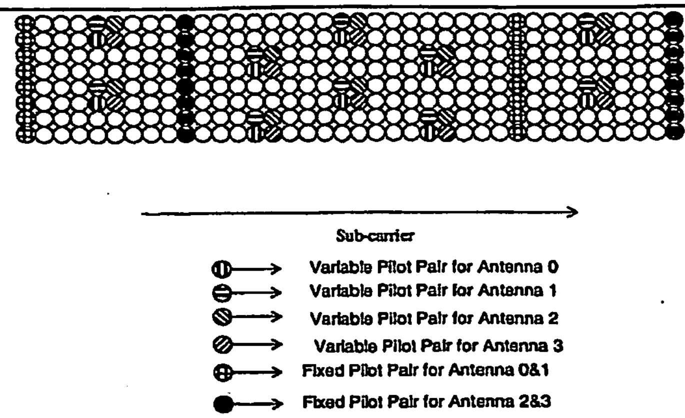

Figure 12 Variable and fixed pilot for 4 transmit antenna case (Pattern-F4C)

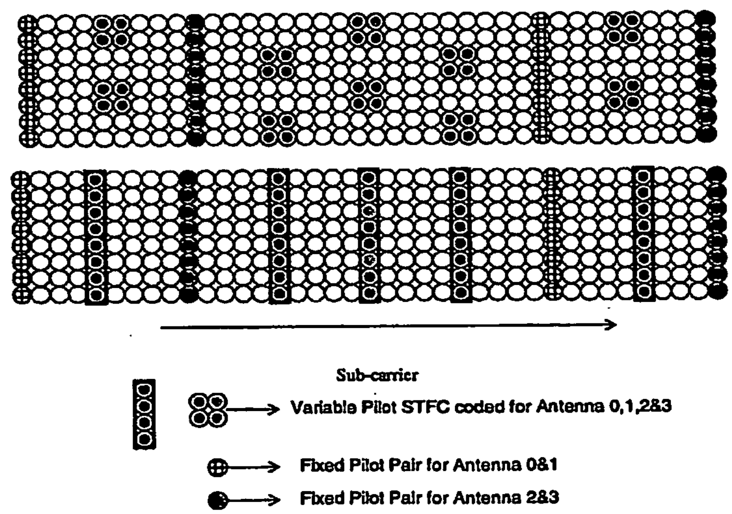

Figure 13 Variable and fixed pilot for 4 transmit antenna case (Pattern-F4D)

3. UPLINK (UL) MIMO PILOT

A user supporting transmission using STC configuration in the uplink, shall use a modified uplink tile, 2-transmit diversity data or 2-transmit spatial multiplexing data can be mapped onto each subcarrier, The mandatory tile shall be modified to accommodate those configurations. Figure 11, 12,13,14 depicts the UL title for STC transmission

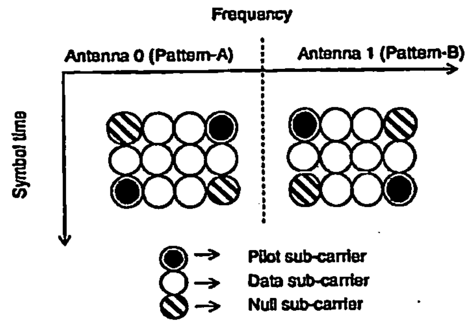

Figure 14 UL MIMO tile Type-I (Pattern-UA)

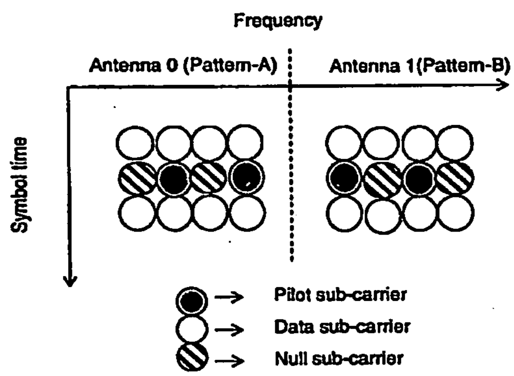

Figure 15 MIMO tile Type-II (Pattern-UB)

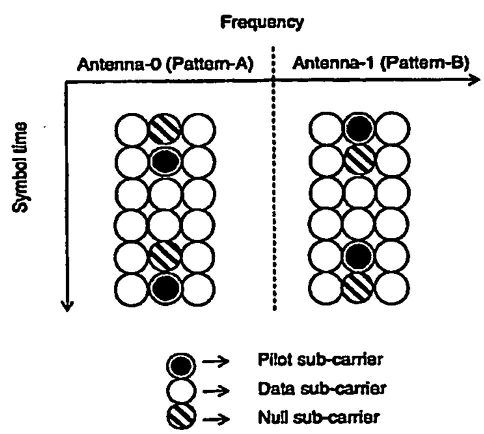

Figure 16 MIMO tile Type-III (Pattern-UC)

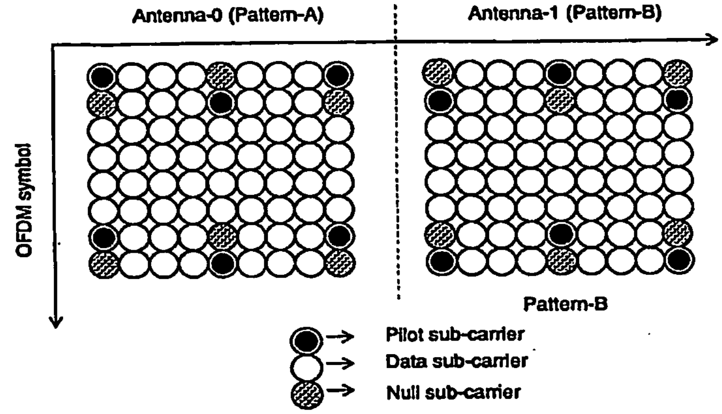

Figure 17 MIMO bin (Pattern-UD)

Two single transmit antenna SS's can perform collaborative spatial multiplexing onto the same subcarrier. In this case, the one SS should use the uplink tile with pattern-A, and the other SS should use the uplink tile with pattern-B. See Figure 11, 12,13,14.

4. SUMMARY

This invention discloses the multiple antennas mapping onto OFDM sub-carrier in time and frequency direction.

WHAT IS CLAIMED IS:

1. Method and apparatus for mapping space time-frequency coded symbol onto an OFDMA sub-carrier in both a frequency and a time dimension for the same code word.

2. The method and apparatus according to claim 1, wherein said mapping can have a hopping pattern in at least one of a space dimension, a time dimension and a frequency dimension.

3. The method and apparatus according to claim 1, wherein said mapping can have a hopping pattern jointly in a space-time frequency dimension.

4. Method and apparatus for OFDM Access ("OFDMA") mapping, for which STFC codes have the following constructions:
   - Code-1: Code rate ¾ space time frequency code
   - Code-2A: Code rate 1 space time frequency code, decodeable with Alamouti decoder.
   - Code-2B: Code rate 1 space time frequency code, Antenna hopped version of Code-2A
   - Code-2C: Code rate 1 space time frequency code, Antenna hopped version of Code-2A
   - Code-3A: Code rate 2 space time frequency code
   - Code-3B: Code rate 2 space time frequency code, Antenna permuted version of Code-3A
   - Code-4: Code rate 4 space time frequency code

5. Method and apparatus for mapping coded symbols in an OFDM system, utilizing one or more *adaptive and flexible* STC, SFC and STFC codes substantially as described in this text

6. Method and apparatus for mapping a pilot symbol for multiple antennas onto OFDM sub-carriers for a *partially loaded* OFDMA system utilizing time-frequency unit hopping.

7. The method and apparatus as recited in claim 6, for which data mapping onto the OFDM sub-carriers are managed by a *single default* MAC carrier carrier assignment procedure for different antenna configurations.

8. The method and apparatus as recited in claim 6, wherein common default data sub-carrier numbers are selected for at least two of said multiple antennas and/or a *sub-carrier swapping* technique is employed to re-allocate the pilot sub-carrier for multiple antennas [thus allowing for a decrease in pilot density with increased number of antennas].

9. The method and apparatus as recited in claim 6, wherein common default data sub-carrier numbers and/or a *data sub-carrier puncturing technique* is employed_to introduce the pilot sub-carrier for multiple antennas [thus allowing for the maintaining or increasing of pilot density with increased number of antennas and permitting performance soft degradation as the number of antenna increases].

10. The method and apparatus as recited in claim 6, wherein common data sub-carrier numbers and *pilot sub-carrier insertion techniques* described above are employed to introduce the pilot sub-carrier for multiple antennas [thus allowing for maintainenance or increasing the pilot density with increased number of antennas].

11. The method and apparatus as recited in claim 6, further comprising pilot patterns Pattern-P2A, Pattern-P2B, Pattern-P2C for an array of two transmit antennas.

12. The method and apparatus as recited in claim 6, further comprising pilot patterns Pattern-P4A, Pattern-P4B, Pattern-P4C for an array of four transmit antennas.

13. Method and apparatus for mapping a pilot symbol for multiple antennas onto OFDM sub-carriers for a *fully loaded* OFDMA system, wherein a set of VaraiblepilotSet and FixedpilotSet are provided for different density usage of pilots [thus permitting best trade-off the overhead and channel estimation quality]

14. The method and apparatus of claim 13, for which pilot density allocation can be dynamic or static.

15. The method and apparatus of claim 13, for which at least one of the following pilot patterns Pattern-P2A, Pattern-P2B, and PatternP2C is provided for a 2-antenna transmit array.

16. The method and apparatus of claim 13, for which at least one of the following pilot patterns Pattern-P4A, Pattern-P4B, Pattern-P4C, Pattern-P4D is provided for a 4-antenna transmit array.

17. Method and apparatus for mapping pilot symbols for multiple antennas onto OFDM sub-carriers for an uplink (UL) OFDMA system, for which a pilot pattern having at least one of the following patterns Pattern-UA, Pattern-UB, Pattern-UC and Pattern-D is established for the channel estimation of UL transmission.